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EVALUATION OF NAVOCEANO PILOT PROGRAM DATA. (U)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report is the last deliverable due under ONR Contract N00014-78-C-0879 and completely fulfills JAYCOR obligations specified in this agreement. It contains the results of a quick-look evaluation of certain data reports, collected under the PILOT program conducted by NAVOCEANO in 1977 and 1978 in the eastern mid-Atlantic, and made available to JAYCOR by NAVOCEANO through NORDA. This evaluation was conducted to ascertain the potential utility of the PILOT data in studying problems of sources, propagation, and sinks of energy in the internal gravity wave band. Based on the reports sent to JAYCOR		

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it was found that these data are generally not of high enough quality nor are the data records complete enough in a temporal or spatial sense to perform the analyses originally perceived possible. This evaluation must be tempered, however, by the fact that the actual data sets were not available for review, either because they had not been processed or there was not sponsor approval. There still remains the possibility that certain portions of the PILOT data could be used to study internal wave phenomena of interest to NORDA Environmental Measurements Program.

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TECHNICAL REPORT
EVALUATION OF NAVOCEANO PILOT
PROGRAM DATA

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TABLE OF CONTENTS

1.0 INTRODUCTION	<u>Page</u> 1
2.0 WORK STATEMENT AND CHRONOLOGY OF EVENTS	4
3.0 "PILOT" DATA ASSESSMENTS ORIGINALLY PROPOSED BY JAYCOR	7
4.0 ANALYSIS OF "PILOT" DATA REPORTS RECEIVED BY JAYCOR FROM NAVOCEANO/NORDA	10
4.1 ATTEMPT TO MEASURE CURRENT SHEAR FROM AN UNANCHORED SHIP	11
4.2 NEAR SURFACE CURRENTS WEST OF GIBRALTAR	12
4.3 OCEAN CURRENTS IN THE PILOT SURVEY AREA	13

1.0 INTRODUCTION

1.0 INTRODUCTION

Continuing efforts by NORDA in characterization of backgrounds of selected physical phenomena in the upper ocean are being directed into the areas of internal wave and turbulence phenomena, two areas of fluid physics which are simultaneously replete with information and devoid of answers to key questions. While significant progress has been made in recent years in the study of internal waves and both the theoretical and observational arenas, present understanding is seriously deficient concerning energy sources for internal waves, energy modulation in the internal wave band and ultimate sinks for internal wave energy.

The most widely accepted theoretical model for describing the internal gravity wave field is that proposed by Garrett and Munk (1972) and later revised (1975). This model assumes that the internal wave is homogeneous and isotropic in frequency-wave number space and has been shown to be accurate within an order of magnitude. Mueller and Siedler (1976) and, more recently, Willebrand, Mueller and Olbers (1977) have carried the Garrett and Munk concepts one step further, by devising consistency relations for determining whether observed fluctuations in field data are consistent with internal waves and, if they are, whether or not the wave field is horizontally isotropic and/or vertically symmetric. These consistency relations were used along with inverse modeling techniques on data collected during the IWEX (Internal Wave Experiment), and provide examples of what can be done in the analysis of data to study the properties of internal waves. Abundant field data were collected by NAVOCEANO as part of the "PILOT" program during the period February 1977 through February 1978 (see Table 1). The survey area was located in the eastern mid-Atlantic (see Figure 1) approximately 800Km east of Portugal.

Additional data were collected during the recent HYDRO 79 field project funded by NORDA and conducted by NAVOCEANO. These data were collected with the express purpose of studying internal wave phenomena in the upper ocean.

TABLE 1: Summary of Field Data Collected Under
Navoceano Pilot Program

	Current Meter Moorings	XBT Casts	CTD Casts	Profiling Current Meter Drops
February 1977	3	32	263 2-36 hr T.S.	12
May 1977	0	41	289 2-36 Hr T.S.	15
August 1977	0		84	17
November 1977	0	24	23 88T.S.	15
February 1978	1	60	24 73 Hr T.S. 36 Hr T.S. 24 Hr T.S.	21

T.S. = Time Series

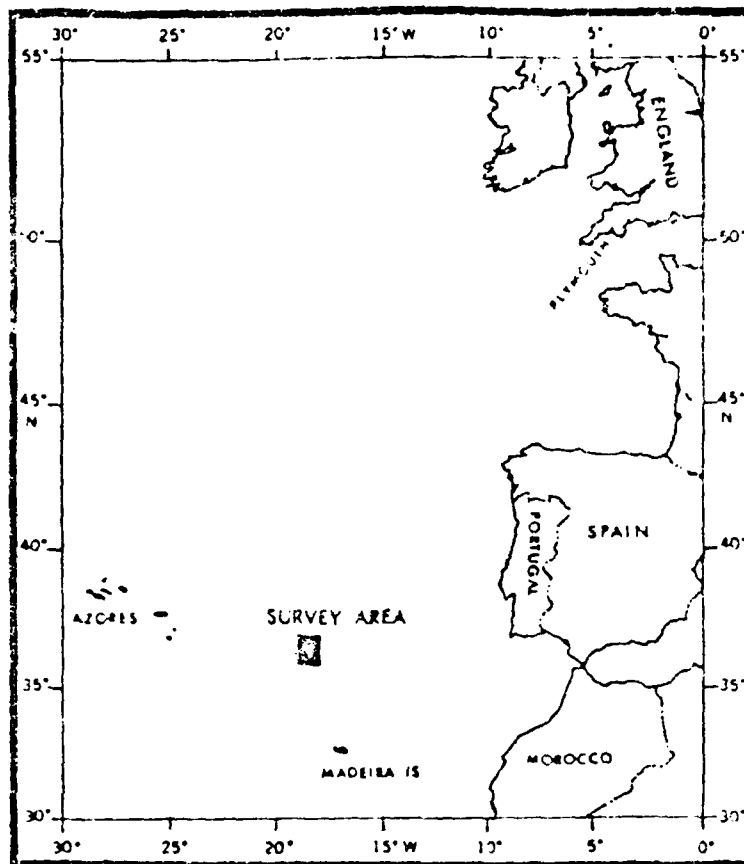


FIGURE 1: NAVOCEANO PILOT Survey Area Located 600 Miles West of Gibraltar, Bounded by Latitudes 30° and 37° N and Longitudes 18° and 19° W. (from Car, 1978)

2.0 WORK STATEMENT AND CHRONOLOGY OF EVENTS

2.0 WORK STATEMENT AND CHRONOLOGY OF EVENTS

In a proposal submitted to NORDA in April 1979, JAYCOR proposed to perform several research tasks with the "PILOT" data sets in an assessment of the adequacy of these data for studying internal wave phenomena. JAYCOR agreed to work cooperatively with NAVOCEANO to obtain copies of "PILOT" data in its most advanced form of processing, preferably in technical report form, and to then perform the following tasks:

- Task 1. Intercompare the water bottle data, calibration data, and the actual field data (whether from the CTD, XBT, or PCM) to determine how good the data sets really are. This form of quality control will determine the magnitude of instrument drift, and the characteristics of the instrument changes. Preliminary survey of the data report on the CTD data collected in February and May 1977 indicate that the quality control and calibration (at least for that instrument) were excellent. However, there are still a number of sets for which this has not been done.
- Task 2. Compare the time series data for the PCM, CTD, and current meters to determine similarity of time responses of various sensors. This establishes record format requirements necessary for making data comparable from, for instance, the CTD and the PCM.
- Task 3. Determine the continuity of the data records from the various instruments. If there are significant gaps in the records then there will be concomitant limitations on the value of the data.

JAYCOR personnel met separately with Dr. M. Stanley of NORDA, Code 500 and CDR L. Dantzler of NAVOCEANO at NSTL Station, MS, on November 13 and 14, 1979, for the purpose of obtaining the required data and reports necessary to proceed with the proposed tasks. Those meetings resulted in the following understandings amongst NORDA, NAVOCEANO, and JAYCOR:

(1) The "PILOT" data were only partially processed and would not be fully processed until June or July, 1980 at the earliest. The reasons for this delay were several, the most important of which were: that there were problems with the Neil Brown CTD system and consequently in reduction of the data from the CTD; and, NAVOCEANO personnel stopped work on the data in order to participate in the HYDRO 79 planning field exercises, and subsequent data analysis. It was mentioned that a series of technical reports on the "PILOT" data were already completed and would be made available to JAYCOR at RTP through Dr. Stanley within one week of the meeting.

(2) The "PILOT" data itself could not be made available to JAYCOR without prior approval of the program sponsor whose headquarters were in Washington, DC. Such approval would take some considerable length of time if it were at all possible. CDR Dantzler felt that it would be more likely to obtain the HYDRO 79 data because NORDA had funded that study directly; however, he agreed to provide to Dr. Stanley a complete annotated inventory of all "PILOT" data. This inventory was to be forwarded on to JAYCOR in RTP by Dr. Stanley, and should be arriving within one week of the meeting date. CDR Dantzler did make two significant points: on some profiling current meter casts, the ship was allowed to drift so the PCM data are contaminated; and, NAVOCEANO scientists feel they have a proprietary claim to those data and would like to reserve the right of first refusal in the analysis of those data.

(3) The HYDRO 79 data should be more readily available (as mentioned above), and of higher quality for the proposed analyses due to the nature of the experimental design. This data set was to be completely processed by the end of the first week in December, 1979, and in report form by March 1980. The HYDRO 79 data are, however, almost entirely classified with the exception of a small portion of the data set soon to be handed over to NORDA by NAVOCEANO. Included in the HYDRO 79 data are measurements from moored EM and VACM current meters, profiling current meters, CTD time series, XBT, AXBT, and ASVXBT. Some of these data will be analyzed in-house, e.g., by H. Perkins (NORDA) but many of the data sets are being sought for

analyses for NORDA by private corporations. Dr. Stanley indicated that analysis of the HYDRO 79 data by JAYCOR would not be possible since the decision had already been made on which corporation(s) would do that.

In summary, it was agreed that when the "PILOT" data reports and annotated inventory were received from NAVOCEANO via NORDA, (anticipated for the week of November 20, 1979) JAYCOR would assess their utility in addressing basic questions in internal wave and oceanic turbulence phenomena.

3.0 "PILOT" DATA ASSESSMENTS ORIGINALLY PROPOSED
BY JAYCOR

3.0 "PILOT" DATA ASSESSMENTS ORIGINALLY PROPOSED BY JAYCOR

The following excerpts from our original proposal describe in more detail the types of assessments originally envisioned for the data, and the significance of those assessments.

The relationship between fine scale structure, shear, internal waves, and turbulence is known in a semi-quantitative sense at best, and leads to ambiguity and interpretation of field measurements. It is essential that there be developed an understanding of these intimately related features of upper ocean dynamics which can best be done through simultaneous examination of field data and its relationship to theoretical treatments. Results of this type of endeavor should heavily influence future experimental design, instrument development, data analysis, and focus on theoretical areas that need immediate attention. Moreover, given that the data sets from these various instruments are fairly complete, reliable, and comparable it is possible that one can calculate:

- a. Brunt-Vaisala frequencies (the numerator of the Richardson number (R_i) from the CTD data;
- b. Brunt-Vaisala frequencies and shear from the PCM (a cross check on the numerator for the R_i and the denominator for the R_i).
- c. From a. and b. one can then determine the temporal and spatial distribution of the R_i and N^2 , stability criteria for the water column.

One could then investigate and quantify the modulation of internal gravity wave energy and the related properties of the internal gravity wave field in relation to the dynamical stability of the water column and the low frequency circulation. In order to accomplish this, one must be able to measure the low frequency variability which requires time series data and sufficient temporal and spatial resolution of R_i , N^2 , and shear. These data could be obtained from PCM, CTD, and moored current meter data of the type collected in the "PILOT" program provided there is sufficient spatial and temporal overlap of the various data sets.

There are basically two interesting aspects of maintenance of internal gravity waves (mechanisms by which internal wave energy is transported), namely:

1. Through K-H instability which gives rise to turbulence, and,
2. Through critical layer absorption which is a mechanism in which internal gravity wave energy at high frequency is put in lower frequencies.

It would be extremely useful to be able to quantify how active these two mechanisms are in the water column which would entail using moored current meter data and the PCM. From these data one could then address questions of:

- o How well is shear correlated with N^2 ?
- o Are there regions of Kelvin-Helmholtz (K-H) instability?
- o Are there regions in which there is a large amount of shear, but not K-H instability?
- o What portion of the water column (quantify) is characterized by $R_i < \frac{1}{2}$ and what is the dynamic stability of the water column as a function of space and time?

To be able to generate time series of R_i and N^2 in space or spatial series in time is very important to getting at all of the upper ocean dynamics from the high to low frequencies. If, for example, one is interested in turbulence generated by internal waves, then it is possible to take a volume and, based on the criterion of $R_i < \frac{1}{2}$ indicating instability, one can integrate over that volume and have a measure of the percentage of the water column in which the internal waves are generating turbulence, i.e., one can quantify the contribution of internal waves to turbulence in the water column.

From the current meter moorings data, it may be possible to calculate $\frac{\partial u}{\partial x}$, $\frac{\partial u}{\partial y}$, $\frac{\partial v}{\partial x}$, and $\frac{\partial v}{\partial y}$ and to calculate horizontal wave numbers, estimate mean currents, and through vector time series analysis to determine the dominance

of energy in various bandwidths in the internal wave spectrum. One could use this current meter data in the analysis of the modulation of total energy density horizontal isotropy, and vertical homogeneity. For example, time series of anisotropy relative to a coordinate axis may be computed from a single current meter record and further analyzed relative to the low frequency currents or other inputs in a search for sources of energy.

Because of the availability u_x , u_y , v_x , and v_y , information and because one can obtain u and v as a function of z . Assuming there are temperature sensors on the moorings in association with the current meters you will also be able to obtain $\frac{\partial T}{\partial x}$, $\frac{\partial T}{\partial y}$, $\frac{\partial T}{\partial z}$, and $\frac{\partial T}{\partial t}$ from which you might be able to make some implications about vertical velocities through the temperature balance equation:

$$\frac{DT}{Dt} = \frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} + w \frac{\partial T}{\partial z} = \frac{\partial}{\partial x} \left(k^1 \frac{\partial T^*}{\partial x} \right) + \frac{\partial}{\partial y} \left(k^2 \frac{\partial T^*}{\partial y} \right) + \frac{\partial}{\partial z} \left(k^3 \frac{\partial T^*}{\partial z} \right) = 0$$

In fact, a time series of vertical velocity could be developed, and furthermore, from the current meter array, if the low frequency motion turns out to be geostrophic, one can actually compute the vertical velocities directly from the single current meter mooring by making use of geostrophic veering which identically gets rid of horizontal advection of temperature.

4.0 ANALYSIS OF "PILOT" DATA REPORTS RECEIVED BY
JAYCOR FROM NAVOCEANO/NORDA

4.0 ANALYSIS OF "PILOT" DATA REPORTS RECEIVED BY JAYCOR FROM NAVOCEANO/NORDA

The following technical reports were received by JAYCOR from NORDA in mid-December, 1979.

1. Ocean Visibility Measurement During Feb and May 1977, TN 3005-4-78, by Q. Carlson and T. L. McBride.
2. Bathypholometric Measurements of Virtual Bioluminescence in the NE Atlantic During May 1977, TN 3005-3-78, by A. F. Hall and R. F. Staples.
3. Dissolved Trace Metals in Seawater, TN 3005-1-78, by R. Pellenborg and G. M. Leone.
4. Attempts to Measure Current Shear from Unanchored Ship, TN 3005-2-78, by Q. Carlson.
5. Near Surface Current West of Gibraltar, TN 3431-3-79, by O. von Zqeck, D. A. Hale, and R. T. Wahl.

Of these reports only the last two contained any information which could be used in the proposed analyses described in section three of this report. The other three reports dealt with biological, optical, and chemical measurements related to other non-acoustic phenomena of interest to NORDA. The following two sections represent the JAYCOR review and evaluation of the two "PILOT" data reports mentioned above. We have included a brief description of the types of activities conducted, limitations on the data, and suggestions/comments on the utility of the data for addressing the questions enumerated in Section three of this report. In addition, we have included in Section 4.3 a similar review of two reports given to JAYCOR by Dr. Stanley in January, 1979.

Although these two reports were not part of the package conveyed to us by NAVOCEANO via NORDA in December 1979, it is our belief that these may be an indication of higher quality data sets than those described in TN 3005-2-78 and TN 3431-3-79 and should be included for completeness.

4.1 "ATTEMPTS TO MEASURE CURRENT SHEAR FROM AN UNANCHORED SHIP",
TN 3005-2-78, by Q. Carlson.

a. Düing-type profiling current meter was deployed in 12 drops over a 60 x 60 nautical mile survey area over a one week period. The instruments reached depths of 500m from a drifting or slightly underway ship. The sensor was an ANNDERAA current meter and the drop rate resulted in a 1.5 - 4.5m vertical resolution. Navigation was with a single Loran C station, beyond the designed range for Loran C.

NOTES

1. There is sufficient inaccuracy in the navigation to render the velocity profiles of little use since the results from the current recording technique is a superposition of Eulerian and Lagrangian observations with no means of distinguishing between the fraction of the velocity due to each.
2. The temperature scale is incorrect.

SUGGESTIONS AND COMMENTS

1. The technique does not appear to be a feasible one for obtaining velocity profiles.
2. One cannot use a vertical profiling current meter on a moving ship unless you know where the ship is located at all times.
 - a. The vertical model structure of horizontal currents cannot be decomposed into actual, believable results when the observational technique utilizes a combination of Eulerian and Lagrangian measurements without any knowledge of where and when the observations are made.
3. One Loran C line is inadequate for establishing fixed point locations at sea. An analogue is to say that a ship was located at a longitude of 77° E....

4. The drag rate of the AANDERAA, which results in a 1.5 - 4.5m vertical resolution must be resolved before internal wave and turbulence dynamics can be queried without gross reservation.

4.2 "NEAR SURFACE CURRENTS WEST OF GIBRALTAR",

TN 3431-3-79, by O. von Zweck, D. A. Hale and R. T. Wahl.

a. The data report describes results obtained from single current meter mooring in water of 1527m depth located at 35°41 N, 7°42'W for 16 days. The array consisted of ten current meters (2 AANDERAA's and 8 VACM's) located at irregular intervals between 108m and 153m on a subsurface mooring. CTD time series were also obtained, but results are not included in the report. Data from eight of the current meters (at depths of 113m (AAN), 117, 121, 130, 134, 137, 150, and 153m) are presented in this report. The report included:

1. Unfiltered time series of salinity, depth and u & v velocities.
2. Salinity vs. depth histograms and joint histograms.
3. Unfiltered time series of temperature.
4. Pressure time series from the AANDERAA current meter at 113m depth.
5. Filtered stick plots.
6. Progressive vector diagrams.

NOTES

1. The recorded AANDERAA current speeds seem to have an upward bias relative to the VACM.
2. Temperature time series appear coherent but are non-stationary i.e., the thermocline appeared to rise midway through the deployment.
3. Pressure shows that the mooring decreased in depths by approximately 4m over the first half of the record. This accounts for part of the temperature non-stationarity. Semi-diurnal oscillations ranging 4m pervade the record.
4. Velocity records are dominated by inertial and higher frequency oscillations.

SUGGESTIONS AND COMMENTS

1. Velocity records appear coherent. Mooring motions is primarily semi-diurnal whereas the velocity fluctuations are mainly inertial. One could analyze the energy level and vertical propagation of these inertial motions and higher frequencies.
2. The short record length inhibits resolution, however, consistency relations of the Müller-Siedler type can be computed over the internal wave range using this data. This would provide information from upper ocean data which at present is sparse.
3. Sixteen day records are too short to analyze modulation relative to meteorological forcing and low frequency current which have time scales around 5 days and longer and do not appear energetic in these records. However, a qualitative comparison of, for instance, daily high frequency energy levels with properties of the water column (N^2 , $lv_z l^2$, R_i) might be interesting.
4. Vertical wavenumber bandwidth for the internal wave range could be computed from γ vs. separation.

4.3 "OCEAN CURRENTS IN THE "PILOT" SURVEY AREA",

TN 3005-5-78, by Martial Car.

"CONDUCTIVITY, TEMPERATURE AND DEPTH MEASUREMENTS IN THE EASTERN ATLANTIC", TN 3005-6-78, by R. A. Peloquin, H. Iredale, and T. Bolton.

a. Data report for temperature, conductivity and pressure measurements obtained during February and May 1977, in the "PILOT" Survey Area. Calculations which can be performed with these data essentially encompass Brunt-Vaisala frequencies, vertical and horizontal shears of currents and vertical and horizontal temperature and salinity gradients, Richardson numbers and the temporal variations of all of these quantities.

NAVOCEANO's data filtering capabilities at the time of production of these reports are in question since the products produced naturally lead to the evaluation of the above parameters, if the proper filtering techniques are used, and these calculations were not made. Data sets are quite good.